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THE USE OF RAPID READING AIRBORNE DUST INSTRUMENTS IN MINES AND MILLS

G. KNIGHT

ELLIOT LAKE LABORATORY

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by

G.Knight*

ABSTRACT

It is apparent that rapid-response direct-reading dust measurement instruments could permit more frequent dust surveys than the commonly used microscope counting or long period gravimetric techniques.

The major problem in such applications is correlation with the instruments used for assessing health effects or legislative compliance. The major difficulties in obtaining a correlation are:

1. The very large variations in dust concentration that are found at any one place or job; and
2. The differences in the relative estimates of dust clouds because instruments differ in the parameters used to assess them, and because dust clouds differ in size distribution and composition.

These problems are discussed together with objectives and calibration protocols for using rapid-response direct-reading instruments.

It is suggested that surveys conducted with these instruments could be useful for faster detection of dust control problems. They could not be expected to eliminate the desirability of personal dust sampling, but could probably decrease the frequency in concentrated operations in mining such as mills.

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*Research Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.

UTILISATION D'APPAREILS DE MESURE DE LA POUSSIÈRE À LECTURE RAPIDE DANS LES MINES ET LES USINES

par

G. Knight*

RÉSUMÉ

Il est évident que les appareils de mesure de la poussière à réponse rapide et à lecture directe pemettraient un contrôle plus fréquent de la poussière que ne le permettent le comptage au microscope ou les techniques gravimétriques de longue durée que l'on utilise habituellement.

Le problème principal que posent ces méthodes est la corrélation des données avec les données provenant d'instruments servant à évaluer les effets sur la santé ou le degré de conformité à la loi. Les difficultés principales qu'il faut solutionner pour faire la corrélation des données sont les suivantes:

1. La très grande diversité des concentrations de poussière que l'on retrouve dans un endroit ou un milieu de travail en particulier; et
2. Les différences entre les résultats des diverses évaluations de nuages de poussière en raison de l'application de paramètres différents aux instruments utilisés pour faire les évaluations et des différences dans la dimension et la distribution des nuages de poussière.

Le rapport présente une étude de ces problèmes et examine l'utilisation d'appareils à réponse rapide et à lecture directe en ce qui a trait aux objectifs visés et à la façon de procéder pour la calibration.

Il semblerait que les contrôles effectués à l'aide de ces appareils seraient utiles pour la détection plus rapide des problèmes que pose le contrôle de la poussière. On ne peut s'attendre à ce que ces instruments éliminent la necessité de faire des échantillonnages de poussière sur une base privée, mais ils serviraient probablement à éliminer la nécessité de contrôles fréquents dans les installations minières, telles les usines.

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*Chercheur scientifique, Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources Canada, Elliot Lake (Ontario)

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INTRODUCTION

There are many rapid direct-reading dust instruments available on the market (1). These instruments show promise of permitting technicians to carry out quick and more frequent dust surveys than the existing techniques, such as konimetry with its longer treatment and assessment (microscope counting) time (2).

For the successful application of these dust instruments the objectives of the dust sampling program have to be defined, and the limitations of the measurement system understood. The major limitations that can apply are:

1. The short sampling period and the very high variations of the dust cloud concentration with time.
2. The parameters of the dust cloud that are measured.
3. The relationship of the measured parameters to those relating to the potential health hazard, and/or those measured by the dust sampling instrument defined by legislation. The range of dust size distributions and compositions found has to be considered.
4. The large differences in properties of airborne dust derived from different sources, such as broken mineral, internal combustion engine exhaust and welding may enable source identification.

This report discusses the objectives and limitations of rapid response dust instruments in general. The specific factors relating to types of dust sensors are not considered. The report has been written in response to a number of queries from mine personnel on the characteristics of portable direct-reading dust instruments.

The general points raised are also applicable to continuous monitoring and this is discussed.

DEFINITION OF OBJECTIVES

There are many objectives for which airborne dust assessment could be carried out. Among these are:

1. control of workers' dust exposure;
2. estimation of potential health hazard to which workers are exposed;
3. demonstration of compliance with legislated standards in working places (mines objective);
4. demonstration of non-compliance with legislated standards in working places (inspectors' objective);
5. control of processes, such as air filters and material losses;
6. estimation of safety hazards, such as visibility;
7. estimation of hazards to equipment;
8. demonstration of compliance with emission standards;

and probably others.

The first four objectives have in common the need to compare the dust parameters of the measurement system with those relating to the potential health hazard. The eighth objective has similar considerations in relation to the legislated standards, which may be for health and/or nuisance reasons. The distinction between objectives 3) and 4) lie in the statistical treatment required.

For objectives 5), 6) and 7), rapid reading instruments or continuous monitors may be the most viable solution with the use of ad hoc standards based on meeting the specific objective.

This report is concerned mainly with the use of rapid reading instruments in relation to the first four objectives.

VARIATIONS IN DUST CONCENTRATION

It is usually found that dust concentrations, in common with many air contaminants, follow a logarithmic normal distribution with a very large spread, which increases with decreasing periods of time over which the concentration is averaged. It has been found that if 20 samples are collected on the same job in the same place, then the range is about 7 to 1 for full-shift gravimetric samples on different days, and over 20 to 1 for 4 minute gravimetric samples (3,4). While the variations with the konimeter usually appear less, this is because of subjective effects giving rise to a non-linear compressed dust scale (5).

The true variability in dust concentration from one measurement period to another is very large. This is a major factor in interpreting the results of measurements. The results have to be treated statistically to meet the objectives. The simple suitable statistical techniques available are averaging and quality control charts.

PARAMETERS OF DUST CLOUD MEASURED

The important factors of the dust cloud in relation to human health are the size distribution of the dust insofar as it effects regional deposition, the composition of the dust fraction deposited in each region, its solubility, and its retention time there.

SIZE DISTRIBUTION

Airborne dust entry and deposition in regions of the human respiratory tract are size-dependent. Conventions have been adopted which are applicable to mine problems (6,7).

The important considerations are deposition in the three major compartments of the breathing system:

i) the nose, mouth and throat including larynx;

ii) the bronchial tract;

iii) the alveolar region.

The terms 'inhalable dust', 'nasopharyngeal deposition', 'bronchial deposition', larynx cut', 'alveolar deposition' and 'respirable dust' are used to describe the relationship between the size of airborne dust and the human reaction. The definitions of these terms in brief are:

Inhalable dust - that fraction of the airborne dust that can enter the nose (or mouth).

Nasopharyngeal deposition - that fraction of the dust deposited before and in larynx.

Bronchial deposition - that portion of the dust which is deposited in the ciliated air passages in the lungs.

Larynx cut - the size selection curve defining mean human penetration past the larynx.

Alveolar deposition - that portion of the dust which is deposited in the furthest depths of the lungs where it forms a potential pneumoconiosis hazard.

Respirable dust - the fraction of dust penetrating a size selector intended to simulate dust deposition in the bronchial tract.

Most dust sampling instruments have a size selection cut at their entries. The only exceptions are those with isokinetic entries. Isokinetic entries are generally not feasible in ambient conditions. So called 'total' dust samplers all have entry selection and may under or overestimate coarse dust particles dependent on conditions. There are attempts now to produce dust samplers that simulate the nasal entry of dust. These are called 'inhalable' samplers (6).

In most mines the major potential health hazard is dust in the

respirable size range and respirable size selection is often used.

COMPOSITION

The health hazard of an airborne dust fraction depends on its composition. In mining the major consideration is normally the presence of quartz or rock (asbestos) fibres in the respirable fraction of the dust, because these are able to produce human disease at lower dust concentrations than most common minerals. Thus, an important factor is: Does the instrument measure these components separately, or only the total respirable dust? Another consideration in mining is the distinction between respirable dust from broken mineral and that particulate in the exhaust from a diesel engine. A two-channel sensor to separate mineral dust from diesel exhaust particulate is being developed (8).

SYMBOLIC RELATIONSHIPS BETWEEN DUST INSTRUMENT AND HUMAN BODY RESPONSES

To assist understanding, a simple symbolic treatment of the instrumental and human response to dust as affected by the complex of composition and size distribution is given. The instrumental responses are usually additive. The human responses, however, in different regions and compositions are probably not additive. One cannot, for instance, add directly bronchitis from coarser dust deposition in the bronchial tract to pneumoconiosis from respirable dust deposition in the alveolar region.

Each instrument and the human body can be treated as having a specific response to each component of each dust size fraction.

$$R = \sum_{i=1}^{n} SC_i$$

where, R is the total response

SC_i is the response to the size-component fraction of the dust

Σ_i is the subscript referring to the component

denotes summation over the n size component dust fractions.

In mine dust sampling the major components of airborne dust of interest are:

Coarse non-inhalable dust	-	C
Inhalable dust	-	I
Bronchial deposition dust	-	B
Respirable dust - total		RT
- mineral		RM
- quartz		RQ
- fibrous		RF
- diesel particulate		RD
Air pollution	-	AP

Thus equations can be set-up:

$$R_H = I_H + B_H + RT_H + RM_H + RQ_H + RF_H + RD_H + AP_H$$

for the human response, subscript H; and

$$R_I = C_I + I_I + B_I + RT_I + RM_I + RQ_I + RF_I + RD_I + AP_I$$

for the instrumental response, subscript I.

In many cases only the major health factor is considered and an appropriate size selection and assessment method is applied to the instrument response. Two examples are:

$R_H = RQ_H$ with $R_I = RQ_I$ (XRD analysis of gravimetric sampler), and

$R_H = RF_H$ with $R_I = RF_I$ (microscope fibre count).

These can be considered as examples of a specific measurement technique as contrasted to the semi-specific technique:

$R_H = RQ_H$ with $R_I = RM_I$ (Konimetry-microscope count of ashed particles)

and non-specific technique:

$R_H = RF_H$ with $R_I = RT_I$ (respirable gravimetric weight)

There can be substantial differences between the specific human, RF_H, and the specific instrumental, RF_I, responses because of differences in dust

size and composition effects.

In semi-specific and non-specific cases the effects of varying size distribution and of mixture of dust from different sources, and the wide variation that occurs in their ratio also have to be considered. In underground mining the ratio of inhalable to respirable dust is greater near the source, and where diesels are used the ratio of mineral dust to diesel exhaust particulate varies over the range from less than 0.1 to more than 10.0.

COMPARISONS OF DUST SAMPLERS

Comparisons between dust samplers have to consider all the factors above as well as the errors associated with each measurement.

The effects of dust concentration variation with time and space can be minimized by sampling side-by-side in the identical sampling period. The results of comparisons between types of samplers measuring the same dust parameter, respirable size-selecting gravimetric samplers, has been considered previously (9,10). It was shown that a linear relationship could be assumed in all cases and that arithmetic errors predominated when the mass of dust collected was small and geometric errors predominated for a high mass.

For direct-reading instruments, the parameters measurable are seldom the most suitable for estimating the health hazard, thus introducing further errors. As an example, a comparison between rapid response, 4 minute, gravimeteric samplers and a microscope fibre count on a 90 minute period membrane-filter sample is shown in Fig. 1. The gravimetric assessment is given as the mean of 10 or 20 evenly spaced measurements taken side-by-side over the 90 minute period of the membrane filter sample. The features of this comparison are:

1. the very poor correlation in the lower concentration region;
2. the reasonable correlation in the higher concentration region;

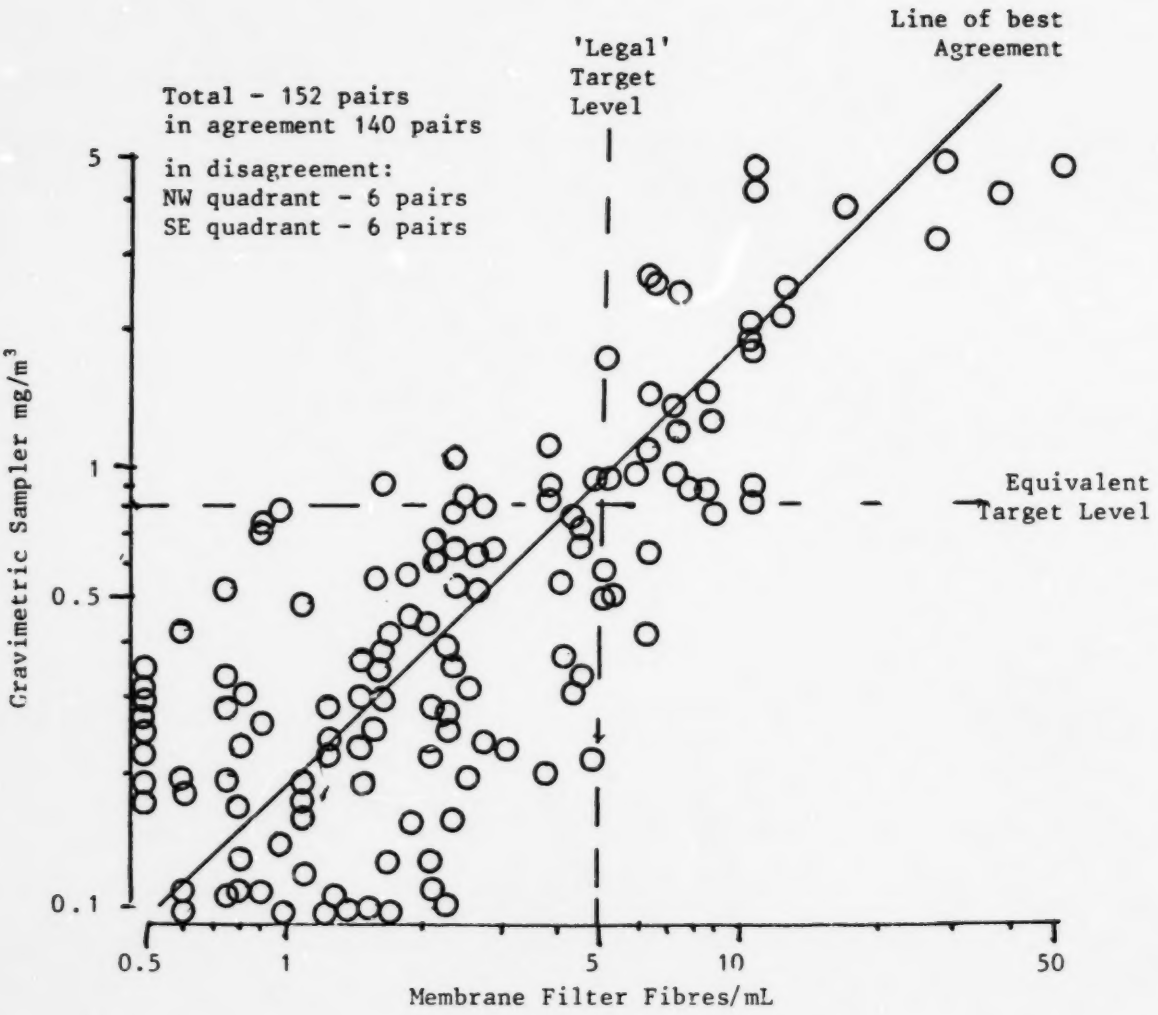

Fig. 1 - Comparison of two samplers assessing dust by different parameters showing equivalent target levels for each.

3. the best estimate is a linear relationship between the two variables using the statistical techniques described (9,10);
4. the true spread, at least two to one, found in the ratio of the two measurements due to differences in dust cloud properties;
5. a target level, 0.8 mg/m^3, can be found to equate to the 5 fibre/ml target level then in force. For these two target levels it was found that both techniques agreed in placing 85% of the sites above or below the target levels, and disagreed on the remaining 15%.

In comparisons between this pair of samplers in other mines the correlation was worse. It appeared that the main reason was because of the large variations of concentration with time and the failure to determine gravimetrically a reasonable mean for the longer membrane filter sampling period, either because too few gravimetric samplers were taken in the 90 minute period, or because they were taken at other times altogether.

These comparisons suggest that it is possible to determine a target level for dust measurement by a rapid-reading instrument that will give equivalent control to dust measurement by the accepted, or legally defined dust sampler.

CALIBRATION OF RAPID RESPONSE SAMPLING PROGRAMS

Two possible protocols for determination of the rapid-reading instrument target level are:

1. careful comparisons determining the mean dust concentration over the measuring period of the longer period sampler;
2. a large number of replicate samples taken by both samplers over an extended period at each sampling site.

The second protocol has the advantage that it could be used to compare widely different programs, such as a fixed station rapid-sampling program with

a personal sampling program aimed at estimation of workers exposure. The fixed station rapid-sampling program could have as its major objective quick detection of dust control failures and their prompt repair, using target levels for each station. These target levels could then be based on engineering feasibility and/or administrtive control. Existing low levels could be targeted low with the intention of maintaining workers exposure as low as reasonably attainable, the ALARA principle. High levels at stations where men only spend a small proportion of their time could be targeted high in accordance with administrative control and the high cost of improvement in relation to the resultant small reduction in exposure.

Because of the large variations in dust concentration with time it is necessary to use statistical analysis of the measurements to detect a significant change in dust concentration. Thus, generally, the larger the change the quicker it can be detected and quality control techniques would appear useful.

DISCUSSION

It is obvious that more frequent dust surveys could be carried out with rapid-response direct-reading instruments than with the longer period samplers or microscope counting techniques now in common use.

It seems possible that such more frequent surveys could detect dust control failures in extended plants more quickly than could the existing surveys. It is clear, however, that such surveys are not likely to determine workers exposure to dust or compliance with legislative requirements with adequate accuracy. It is suggested that a personal full-shift dust sampling program will also be required. The frequency of personal sampling could probably be reduced substantially when the rapid-response instrument surveys are in full operation and dust control is effective. Vigilance must be

maintained to guard against changes in operations leading to substantial changes in dust cloud properties which could nullify the calibration previously conducted.

A major factor which could give rise to erratic dust readings is occasional maintenance operations, such as concrete breaking (building modifications) and welding. These may give rise to high dust concentrations for short periods. The dust instrument operator should record unusual events, such as these, so that first they are recognized as dust sources in their own right, and secondly that they are not misinterpreted as failures in dust control equipment.

In continuous monitoring, the sensor is being used at a fixed site. Thus, it monitors the main dust sources at the site. If there is only one significant source, such as a crusher during operating periods, or the outlet from a filter bag installation, then the interpretation of the results is relatively simple, and if desired a control could be operated. For many situations, however, there is more than one independent source, such as broken rock and diesel exhaust in underground mines and the estimation of an appropriate control response may be difficult.

REFERENCES

1. Partial list of manufacturers: Leitz, Germany - Tyndalloscope; GCA Mass U.S.A. - respirable dust monitors - fiber dust monitor; MDA, Ill, U.S.A. - dust indicator; TSI Minn. U.S.A. - respirable particle mass monitor.

2. Anon., "Konimeter dust sampling as practised by MAPAO engineers"; Mines Accident Prevention Association of Ontario, Toronto; undated.

3. Knight, G., Kirk, B., Sutarno, R. and Stefanich, W., "Personal dust sampling in mines - statistical analysis"; in P. Mousset Jones (Ed.) Second International Mine Ventilation Congress; Soc Min Eng Am Inst of

Min Met and Pet Engrs, New York; 1980.

4. G. Knight, unpublished report.

5. Cochrane, T.S., Knight, G., Richards, L.C. and Stefanich, W., "Comparison of dust sampling instruments"; Mines Branch Research Report R250, CANMET, Energy, Mines and Resources Canada; 1971.

6. International Organization for Standards, "Air quality - particle size fraction definitions for health related sampling"; Technical Report 7708; Int Org for Standards, Geneva; 1983.

7. Knight, G., "Proposal for particle size fraction definitions for health related sampling"; Submitted to Ann Occup Hyg; 1985.

8. Motycha, J., "Development of sensors for separate assessments of diesel exhaust particulates and respirable dust in mine atmospheres"; CANMET Contract Report SQ83-00131; CANMET, Energy, Mines and Resources Canada; 1984.

9. Knight, G. and Moore, E., "Comparison of dust samplers for use in hard rock mines"; submitted to Am Ind Hyg Assoc J; 1985.

10. Knight, G. and Moore, E., "Comparison of dust samplers: statistical analysis techniques"; Submitted to Am Ind Hyg Assoc J; 1985.